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Working Time of Bull Trawlers during Alaska Pollack Fishing—II.*

The Variation of the Length of the Hauling-fastening Time Relating to the Amount of Catch, the Depth Fished, and the Height of Wind Wave

By

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The Alaska pollack fishery in the Bering Sea is one of the newly developed and most important fisheries in Japan. This fishery is mainly conducted in the three types, one being the stern ramp factory trawling, another being the factory ship type, and the other being the Danish seining supplying the factory on land with the material fish. The present series of reports dealt with the second one. The flotilla supplying the factory ship with the material fish consists of the two types of boats—the Danish seiner and the bull trawler. In the early stage of this fishery, the former occupied the leading portion of the flotilla, but was substituted by the latter year after year, and on the present days the latter occupies the leading portion. This was mainly due to the following administrative reason: the bull trawler in Japan developed for fishing in the Eastern Sea. The fishing enterprise of the factory ship owns many bull trawlers. On the other hand, the Danish seiners developed and worked mainly in the northern half of Japan and were familiar with the fishing for the cold water species. And in the earlier stage of this fishery, the bull trawlers could not win against the Danish seiners in the economic efficiency. But the catch in the Eastern Sea declined, and the bull trawlers were obliged to fish in the other waters, and they were converted into also suitable for fishing the cold water species. The work pattern of the Danish seiners for this fishery was examined in the preceding series of reports[1)-11)], but that of the bull trawlers was examined in the present series because of above-mentioned reasons. The work of the bull trawlers consists usually of the following steps: shooting, towing, brailing, and shift. But the catch in the present case was too good to be brailed into the fish hold. And the work pattern after hauling up the net body was changed into as follows: the cod end containing the catch was separated from the net body and made fasten alongside the boat, and was directly taken inboard of the factory ship. The bull trawling was done by a pair of boats and the net was shot from one of the boats sometimes during the fastening work of the preceding haul by the other boat. And the

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working speed of this step of work was not examined in the present series, for it was doubtful whether it would be necessary to conduct this step at full speed or not necessary to do so, and whether this step would be begun before or after the finish of the fastening work. The time for the second step of work, i.e. for the towing work, was examined in the preceding report[12] of this series. The original records had no description on the boundary time between the hauling work and the work of making fasten the cod end. Accordingly, the present report dealt with the change of the working speed of the hauling-fastening work according to the amount of catch, the depth fished, and the height of the wind wave.

Material and Method

The flotilla studied here had the three pairs of the bull trawlers of the same size and the same power. Each of the pairs of the boats sent the telegrams to the factory ship several times a day. The materials used in the present report were the complete set of these routine telegrams throughout the season of 1964 from April 18 to Sept. 20. Among many items in these telegrams, the records on the following itmes for respective hauls were used in the present report: the boundary time between the towing work and the hauling one (t_3), the time at the finish of the work of making fasten the cod end (t_4), the echo-sounded depth just before shooting the net, the amount of catch, and the grade of wind wave during towing. The hauling-fastening time (abbreviated to t_h) in the present report defined the time interval between t_3 and t_4. The boundary times in the original records were measured in minutes. But t_h reconed were aggregated into the classes of the nearest 10-minute intervals, because the accuracy of the time measuring and the range of the distribution of t_h were taken into account. The change of t_h in accordance with the change of the above-mentioned three factors was examined after the transformation into $\log(t_h - 19)$. The amount of catch by a haul was recorded in tons ranging from 0 to 35 tons. The echo-sounded depth was recorded in meters ranging from 40 to 150 m because of the legal restriction of the workable depth. This was used after the aggregation into the nearest 10-m intervals, for the range of the distribution and the accuracy of sounding were taken into account. The telegram had the descriptions on the echo-sounded depth just before the finish of towing too. If the difference between the sounded depth just before shooting and that just before the finish of towing was larger than 20 m, the average of them was used. The height of wind wave was described in the grade number according to the standard shown in the first report of this series, and this factor could not be used as one of the independent variables.

As the present report dealt with the regression of the length of the hauling-fastening time (t_h) on either one or both of the amount of catch (x in tons) and the depth fished (y in meters) after the stratification of the records according to the grade of wind wave (w), the constant and the coefficient of the regression equations were defined as follows:

a_{iw} ..... Those of the multiple linear regression equation of $\log(t_h - 19)$ on x and y estimated from the records of the hauls conducted under the wind wave of the grade w. The notation of the first suffix, i, was as follows:

$$\log(t_h - 19) = a_{0w} + a_{1w}x + a_{2w}y$$

b_{iyw} .... Those of the linear regression equation of log $(t_h - 19)$ on x estimated from the records of the hauls from the $10 \times y$ m zone under the wind wave of the grade w. If the equation was estimated pooling the records of all the depth zones, y was omitted. The notation of the first suffix, i, was as follows:

$$\log(t_h - 19) = b_{0yw} + b_{1yw}x$$

c_{ixw} .... Those of the linear regression equation of log $(t_h - 19)$ on y estimated from the records of the hauls yielding a catch of x tons under the wind wave of the grade w. If the equation was estimated pooling the records of all the catch classes, x was omitted. The notation of the first suffix, i, was as follows:

$$\log(t_h - 19) = c_{0xw} + c_{1xw}y$$

1. The type of frequency distribution of the length of hauling-fastening time

The fishing work of the bull trawlers in the present case consisted of the following steps: the shooting work, the towing one, and the hauling-fastening one. The speed

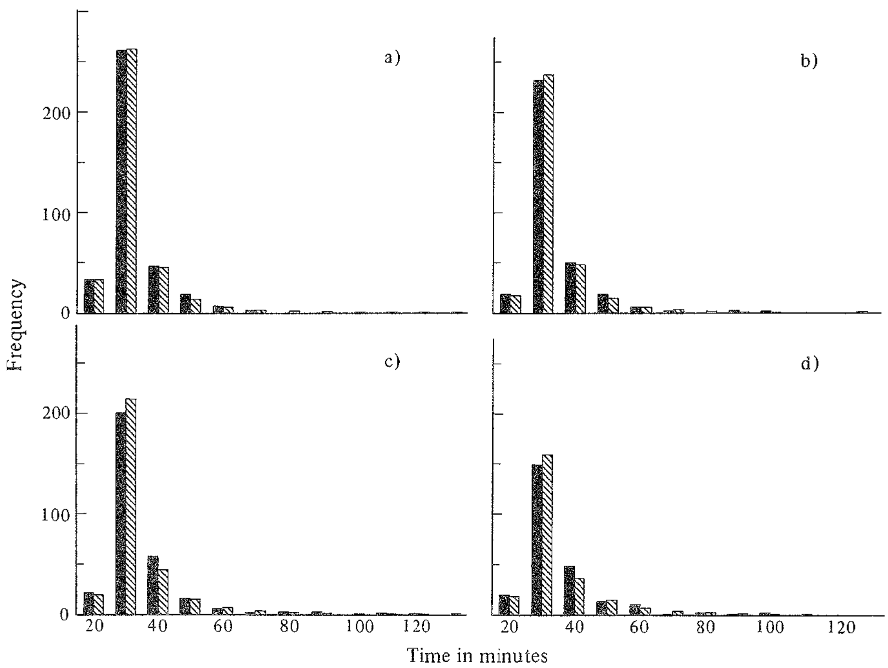

Fig. 1. Four examples of the frequency distributions of the length of hauling-fastening time.

a) Under the wave grade 2 χ_0^2=5.70 with 3 degrees of freedom $0.25 > \Pr\{\chi_0^2 > \chi^2\} > 0.10$

b) Under the wave grade 4 χ_0^2=1.06 with 3 degrees of freedom $0.90 > \Pr\{\chi_0^2 > \chi^2\} > 0.75$

c) Under the wave grade 5 χ_0^2=4.91 with 3 degrees of freedom $0.25 > \Pr\{\chi_0^2 > \chi^2\} > 0.10$

d) Under the wave grade 6 χ_0^2=4.21 with 2 degrees of freedom $0.25 > \Pr\{\chi_0^2 > \chi^2\} > 0.10$

Note: The solid histogram shows the observed distribution, but the hatched one shows the estimated $\log(t_h - 19)$ normal distribution.

of the first step depends mainly on the construction and performance of the boats, although there remained a doubt as to the fact that this step would be conducted at a reduced speed in some of the shootings. The speed of the second step was mainly decided by the skipper's will, although the influence of the density of the objective fish, the extent of trawlable ground, and the distribution of the fellow boats (not only the fellow bull trawlers but also the fellow Danish seiners) could not be neglected. In contrast with them, the speed of the hauling-fastening work under consideration in the present report depends mainly on the construction and performance of the boats, but is modified by the working conditions of the hands.

As the preliminary step of the examinations, the records were stratified according to the grade of wind wave, and the type of the frequency distribution of the hauling-fastening time was examined by comparing with some theoretical distributions. As shown in Fig. 1, the observed hauling-fastening time ranged from 20 min. to longer than 120 min. showing a tailing in the direction of long work. The observed distributions were agreeable neither to the normal distribution nor to the logarithmic one, because of the severe tailing. The hauling-fastening time (t_h) was transformed into log (t_h – 19), for t_h showed a clear tailing and its minimum was 20 min. Then, the distributions became agreeable to the normal distribution. In the further examinations, accordingly, the value of t_h was used after the log (t_h – 19) transformation.

2. The multiple linear regression on the amount of catch and the depth fished

Among many factors described in the original records, the amount of catch (x in tons), the depth fished (y in meters), and the grade of wind wave (w) were chosen as the factors most probable to have a strong influence on the working speed. But the last one was not applicable as one of the independent variables, for described in the grade number covering the unequal range of wave height according to the grade. Accordingly, the regression of log (t_h – 19) on x and y was examined after the stratifi-

Table 1. The multiple linear regression equations of the hauling-fastening time (t_h in min.) on the catch (x in tons) and the depth of the fishing grounds (y in m) under respective grades of wind wave (w).

$$\log (t_h - 19) = a_{ow} + a_{1w}x + a_{2w}y$$

Grade of wind wave (w)	a_{0w}	a_{1w}	a_{2w}	F_x	F_y	n_2
1	0.1878	0.0277	0.0050	10.24 **	3.87	64
2	0.5230	0.0235	0.0029	50.54 **	31.58**	366
3	0.6165	0.0220	0.0023	93.48**	20.50**	562
4	0.5687	0.0236	0.0024	102.74 **	10.89**	327
5	0.9501	0.0228	−0.0007	46.54**	0.41	304
6	0.5500	0.0336	0.0023	43.73**	4.39*	242
7	1.7515	0.0212	−0.0074	11.82**	6.65*	97
8	1.0419	0.0000	−0.0000	0.00	0.00	5

Note : df . . . n_1 = 1 n_2 = the value shown in the table
*significant at 0.05 level ** significant at 0.01 level

cation of the records according to the grade of wind wave, for the purpose of finding out an outline of the change of the hauling-fastening time. And the following results were obtained (Table 1): the hauling-fastening time got significantly longer in accordance with the increase of the amount of catch under all the wave grades except the grade 8 (the insignificance of the coefficient $a_{1.8}$ may be due to insufficient sample size) and in accordance with the increase of the depth trawled under all the wave grades except both of the extremes and the grade 5.

3. The linear regression on the amount of catch

In the ordinary way of bull trawling, the working time after hauling up the net body increases in accordance with the amount of catch, for the catch was brailed out.

Table 2. The linear regression equations of the hauling-fastening time (t_h in min.) on the catch (x in tons) under respective grades of wind wave (w).
$\log(t_h - 19) = b_{0.w} + b_{1.w}x$

Grade of wind wave (w)	Range of x	$b_{0.w}$	$b_{1.w}$	F_0	n_2
1	1 — 30	0.6863	0.0326	14.71**	65
2	0 — 30	0.8407	0.0196	33.83**	367
3	0 — 30	0.8752	0.0214	85.55**	563
4	1 — 39	0.8497	0.0236	99.75**	328
5	0 — 32	0.8745	0.0229	47.15**	305
6	0 — 20	0.7873	0.0357	50.95**	243
7	0 — 20	0.9777	0.0204	10.41**	98
8	3 — 15	1.0414	0.0000	0.00	6

Note : df . . . $n_1 = 1$ n_2 = the value shown in the table
* significant at 0.05 level ** significant at 0.01 level

Table 3. The results of the comparison between $b_{1.w}$ under different grades of wind wave (w) through the t-test.

Grade of wind wave (w)	1		2		3		4		5		6		7	
	t	n	t	n	t	n	t	n	t	n	t	n	t	n
1			1.64	432	1.64	628	1.35	393	1.25	370	−0.35	308	1.17	163
2					−0.45	930	−0.98	695	−0.69	672	−2.67**	610	−0.10	465
3							−0.65	891	−0.38	868	−2.75**	806	0.14	661
4									0.17	633	−2.33*	571	0.47	426
5											−2.15*	548	0.31	403
6													1.72	341
7														

Number of the combinations showing significant difference	L	S	L	S	L	S	L	S	L	S	L	S	L	S
		1		1		1		1			4			

Note: *significant at 0.05 level **significant at 0.01 level
L: significantly larger than the other $b_{1.w}$ S: significantly smaller than the other $b_{1.w}$

The present case was different from the ordinary way in the work pattern after hauling up the net body. The catch was not brailed out, but the cod end containing the catch was separated from the net body and made fasten alongside the boat. It may take longer time for making fasten the fully expanding cod end alongside the boat—i.e., the time for this work may also depend on the amount of catch, although the increase of the time for this work in accordance with the increase of catch may be far smaller than that for the brailing work. As shown in the preceding series, the time for hauling up the net body may differ according to the wave grade. And the time for making fasten the cod end may differ also according to the wave grade. These possibilities were examined through estimating the linear regression equations of log $(t_h - 19)$ on the amount of catch after the stratification of the records according to the wave grade.

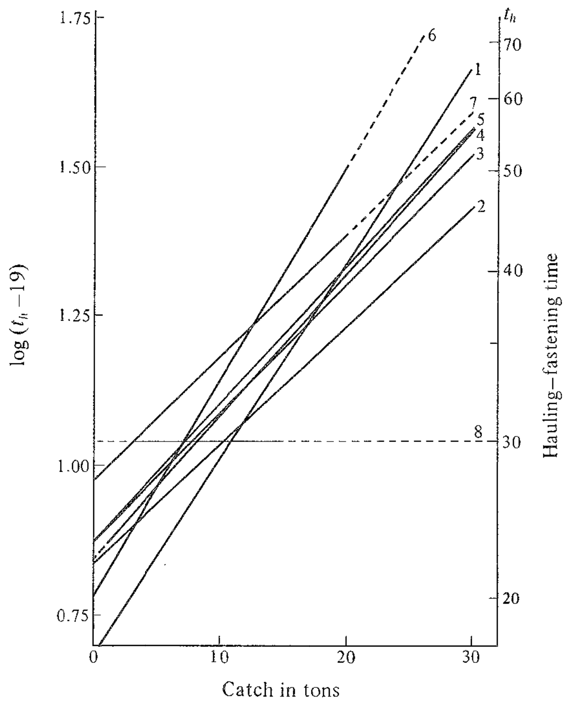

Fig. 2. The estimated regression lines of log$(t_h$ - 19) on the amount of catch, after the stratification of the records according to the wave grade.

Note: The numeral attached to the line shows the grade of wind wave. The thick line shows the relation with the significant regression coefficient. The thin line shows that with the insignificant coefficient. And the applicable range of catch is shown by the part of the solid line.

And the results were shown in Table 2 and Fig. 2. All the $b_{1.w}$ except $b_{1.8}$ were significantly positive (the insignificance of $b_{1.8}$ may be due to insufficient sample size). As shown in Table 3, the difference between any two of $b_{1.w}$ was significant in the four pairs out of the 21 ones, and all the significant differences were due to the large value of $b_{1.6}$. These facts meant that the time for the hauling and fastening steps became longer in accordance with the amount of catch and the increase of t_h due to that of catch was larger under the wave grade 6 than under the other wave grades. The change of log $(t_h - 19)$ with the amount of catch was illustrated in Fig. 2. This figure showed that 1) the difference of t_h due to that of catch was far larger than that due to the difference of the wave grade, 2) the hauling-fastening time under the wave grades 3 to 5 did not show any clear difference according to the wave grade, and 3) the notable difference was found in the following points: short work for the hauls of poor catch under the wave grade 1 and for the hauls of good catch under the wave grade 2, long work throughout the catch classes under the wave grade 7, and for the hauls of good catch under the wave grade 6.

4. The linear regression on the depth fished

The bull trawler uses the longer warps for the deeper ground. And it is probable that it takes time longer for winding up the longer warps, i.e. for hauling up the net from the deeper ground. But the time for the fastening work may have no relation to the depth. This is true to the fishing for the flatfish. But it was doubtful whether this would be true to the fishing for the Alaska pollack, for the cod end containing a good catch floats up faster than the winding speed of the warp, especially when that was hauled up from deep ground. These possibilities were examined through estimating the regression of log $(t_h - 19)$ on the depth fished, after the stratification of the records according to the wave grade. The results were shown in Tables 4 and 5 and Fig. 3. The coefficient $c_{1.w}$ was significant in the six wave grades. The insignificance of $c_{1.8}$ may be due to the insufficient sample size. As shown in Table 5, the difference between any two of $c_{1.w}$ was significant in the 13 pairs out of the 21 ones. These significant differences were due to the large value of $c_{1.1}$ and the small values of $c_{1.5}$ and $c_{1.7}$. The hauling-fastening time was elongated in accordance with the depth more

Table 4. The linear regression equations of the hauling-fastening time (t_h in min.) on the depth of the fishing ground (y in m) under respective grades of wind wave (w).

$$\log (t_h - 19) = c_{0.w} + c_{1.w}\, y$$

Grade of wind wave (w)	Range of y	$c_{0.w}$	$c_{1.w}$	F_0	n_2
1	80—140	0.1889	0.0074	7.88 **	65
2	50—150	0.8150	0.0021	15.59 **	367
3	40—150	0.8668	0.0020	13.34 **	563
4	60—150	0.7953	0.0024	8.33 **	328
5	80—150	1.1875	−0.0010	0.80	305
6	80—150	0.6652	0.0037	10.48 **	243
7	90—130	1.8867	−0.0069	5.26 *	98
8	120—140	1.0414	0.0000	0.00	6

Note: df. . . $n_1 = 1$ n_2 = the value shown in the table
* significant at 0.05 level ** significant at 0.01 level

Table 5 . The results of the comparison between $c_{1.w}$ under different grades of wind wave through the t-test.

Grade of wind wave (w)	1		2		3		4		5		6		7	
	t	n	t		t	n	t	n	t	n	t	n	t	n
1			2.37*	432	2.60*	628	2.28*	393	3.41**	370	1.43	308	3.28**	163
2					0.13	930	−0.30	695	2.54*	672	−1.30	610	2.45*	465
3							−0.40	891	2.52*	868	−1.43	806	2.56*	661
4									2.50*	633	−0.95	571	2.73**	426
5											−2.97**	548	1.57	403
6													2.73**	341
7														
Number of the combinations showing significance difference	L	S	L	S	L	S	L	S	L	S	L	S	L	S
	5		2(2)	1(1)	2(2)	1(1)	2(2)	1(1)		5	2(2)			5

Note: *significant at 0.05 level **significant at 0.01 level

L: significantly larger than the other $c_{1.w}$ S: significantly smaller than the other $c_{1.w}$

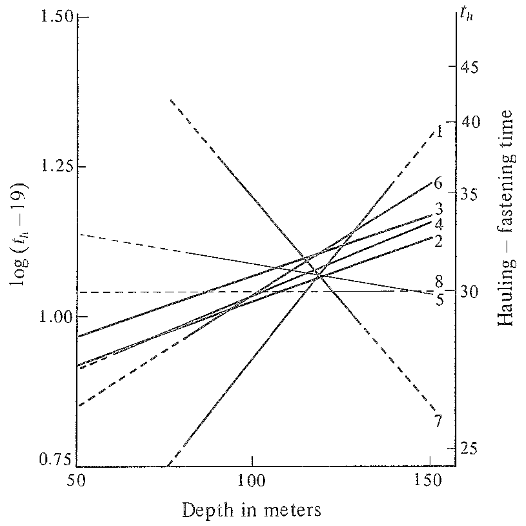

Fig. 3. The estimated regression lines of log(t_h - 19) on the depth fished, after the stratification of the records according to the wave grade.

severely in the wave grade 1 than in the other wave grades, but that was shortened in accordance with the depth in the wave grades 5 and 7. The different influence of the depth on t_h under the different wave grade was illustrated in Fig. 3. The figure showed that 1) the trend of the change of t_h with depth differed according to the wave grade, 2) but the t_h-depth relations in the grades 2, 3, and 4 showed the similar trends to one another, 3) $c_{1.6}$ was larger than the other $c_{1.w}$, but the difference in t_h within the applicable depth range was noticeable only in the deepest extreme, 4) the t_h-depth relation under the wave grade 8 seemed to be somewhat different from those under the other wave grades, but this seeming difference was not worthy to discuss, for the narrow applicable depth range and the small sample size, and 5) the different trends under the wave grades 1, 5, and 7 made the change of the t_h-depth relation in accordance with the wave grade complicated. One of the most probable reasons of making the relation complicated may be the different bathymetric distribution of catch in combination with the clear influence of the amount of catch. This possibility will be examined in the latter section.

5. The linear regression on the amount of catch after the twofold stratification of the records according to the wave grade and the depth fished

The multiple linear regression in the second section showed that the length of hauling-fastening time differed according to the three factors examined. It is a well-known fact that the objective fish shows a well-defined bathymetric change in the distribution. In consequence, the amount of catch and the distribution of the hauls should differ according to the depth. And their bathymetric changes may differ according to the wave grade. The variation of the t_h-depth relation in Fig. 3 suggested the probable disturbance of this factor on the results. For the purpose of finding out the trend of the change of the length of hauling-fastening time in accordance with the amount of catch after eliminating the influence of the difference in the factors of the rest, the regression on the amount of catch was examined, after the twofold stratification of the records according to the depth and the grade of wind wave. And the probable differences of the influence of catch due to the difference either in the depth or in the wave grade were examined by comparing the relations under the different condition of either the depth or the wave grade but under the same condition of the factor of the rest with one another.

5.1 The significance of the estimated regression on the amount of catch

The wind wave during the season varied from the grade 1 to 9, but the boats could not fish on the days of the grade 9. The grade 8 was the fishable limit, but the records in this wave grade were insufficient sample size to be stratified according to the depth or the amount of catch, and they were excluded from the further examinations. The depth fished varied from 40 m to 150 m. The records under respective wave grades were stratified according to the depth into the depth groups of the 10 m intervals. The estimated regression coefficient was significantly positive in the 24 strata out of the 43 ones, insignificantly positive in the 14 ones, but insignificantly negative in the five ones. The insignificantly positive coefficients were mainly found either in the extreme depth zones or in the extreme wave grades. Most of them were as large as the significant ones and were estimated from the records of the sufficient sample size. These facts suggested that the insignificance of the coefficients either in the extreme depth zones or

Table 6. The linear regression equations of the hauling-fastening time (t_h in min.) on the catch (x in tons) after stratification of the records into the depth zones (y in m, 10 m intervals) and the grade of wind wave (w).

$$\log(t_h - 19) = b_{oyw} + b_{1yw}x$$

Grade of wind wave (w)	1				2				3			
Depth zone (y)	b_{0y1}	b_{1y1}	F_0	n_2	b_{0y2}	b_{1y2}	F_0	n_2	b_{0y3}	b_{1y3}	F_0	n_2
50					0.7183	0.0174	2.05	108	0.9421	−0.0079	0.16	54
60												
80	0.2380	0.0744	0.29	3								
90	0.9848	−0.0507	2.19	23					0.8920	0.0217	1.91	30
100					0.8127	0.0278	12.61**	60	0.8827	0.0234	22.35**	90
110	0.9195	0.0242	23.93**	15	0.8389	0.0257	20.27**	45	0.8688	0.0251	52.64**	143
120	0.7469	0.0369	3.11	3	0.7849	0.0251	13.07**	48	0.8841	0.0233	33.43**	93
130					0.9500	0.0119	1.52	32	1.0102	0.0093	0.73	57
140	0.8634	0.0223	0.72	13	0.9752	0.0190	4.98*	60	0.8870	0.0198	17.24**	74
150									1.0414	−0.0000	0.00	6

Grade of wind wave (w)	4				5				6			
Depth zone (y)	b_{0y4}	b_{1y4}	F_0	n_2	b_{0y5}	b_{1y5}	F_0	n_2	b_{0y6}	b_{1y6}	F_0	n_2
50												
60	0.8650	0.0128	0.17	9								
80									0.6267	0.0553	2.49	15
90	0.5534	0.0487	8.63**	43	0.8196	0.0245	9.76**	57	1.2214	−0.0760	3.82	21
100	0.7493	0.0335	5.71*	26	0.9002	0.0272	13.02**	51	0.7894	0.0343	13.96**	72
110	0.8126	0.0264	40.86**	40	0.9774	0.0185	6.17*	41	0.6939	0.0470	15.09**	41
120	0.9507	0.0173	13.87**	51	0.9183	0.0142	3.24	51				
130	0.8914	0.0196	19.05**	64	0.8032	0.0272	7.00*	45	1.2088	−0.0110	0.24	15
140	0.9113	0.0219	34.46**	69	1.0046	0.0090	0.59	40	0.9368	0.0245	10.38**	60
150	1.0939	−0.0084	0.64	11					0.9387	0.0213	13.65*	5

Grade of wind wave (w)	b_{0y7}	b_{1y7}	F_0	n_2
Depth zone (y)	7			
50				
60				
80				
90				
100	1.0475	0.0204	13.18**	59
110	0.8261	0.0260	1.91	25
120				
130	1.2039	−0.0130	1.90	7
140				
150				

Note : df . . . $n_1 = 1$ n_2 = the value shown in the table
* significant at 0.05 level ** significant at 0.01 level

in the extreme wave grades should be due to the roughness of the dependence of t_h on the amount of catch. There were some insignificantly positive coefficients in the intermediate depth zones under the intermediate wave grades; they were far smaller than the significant ones. The insignificantly negative coefficients were mainly in the extreme depth zones. And it may be said that the hauling-fastening time got longer in accordance with the amount of catch.

5.2 The difference of the catch regression according to the wave grade

It is probable that the elongating trend of t_h in accordance with the amount of catch is due to the increasing resistance of pulling the expanding cod end with abundant catch and the increasing work for making fasten the expanding cod end. Then the difficulty in pulling up the expanding cod end and making fasten it may differ according to the wave grade. These facts suggested the possibility of b_{1yw} differing according to the wave grade. As shown in Tables 7 and 8, the significant difference between pairs of b_{1yw} in the same depth zones was found in the 10 pairs out of the 91 ones. They were due to either the large value of $b_{1.11.6}$ or the small value of $b_{1.9.1}$, $b_{1.9.6}$, $b_{1.15.3}$ or

Table 7. The results of the comparison between b_{1yw} under the different grades of wind wave (w) through the t-test.

Depth (y)	50		60		80		90		100		110		120		130		140		150	
Grade of wind wave (w)	t	n	t	n	t	n	t	n	t	n	t	n	t	n	t	n	t	n	t	n
1—2											−0.16	60	0.48	51			0.16	73		
1—3							−2.04*	53			−0.11	158	0.64	96			0.13	87		
1—4							−2.77**	66			−0.29	55	1.11	54			0.02	82		
1—5							−2.65*	80			0.53	56	0.86	54			0.53	53		
1—6					0.17	18	0.47	44			−1.47	56					−0.11	73		
1—7											−0.10	40								
2—3	0.58	162							0.49	150	0.09	188	0.23	141	0.15	89	−0.08	134		
2—4									−0.39	86	−0.10	85	0.95	99	−0.67	96	−0.34	129		
2—5									0.05	111	0.77	86	1.04	99	−0.90	77	0.71	100		
2—6									−0.53	132	−1.71	86			1.00	47	−0.48	120		
2—7									0.76	119	−0.02	70			1.16	39				
3—4							−1.18	73	−0.84	116	−0.23	183	0.91	144	−0.95	121	−0.34	143	0.89	17
3—5							−0.17	87	−0.45	141	0.88	184	1.11	144	−1.19	102	0.92	114		
3—6							2.34*	51	−1.11	162	−2.29*	184			0.62	72	−0.52	134	−4.54**	11
3—7									0.38	149	−0.07	168			0.64	64				
4—5							1.41	100	0.41	77	0.96	81	0.35	102	−0.76	109	1.26	109		
4—6							2.90**	64	−0.05	98	−1.79	81			1.32	79	−0.33	129	−2.46*	16
4—7									1.05	85	0.03	65			1.37	71				
5—6							2.90**	78	−0.60	123	−2.05*	82			1.12	60	−1.16	100		
5—7									0.70	110	−0.41	66			1.10	52				
6—7									1.23	131	0.93	66			0.07	22				

Note :*significant at 0.05 level **significant at 0.01 level

Table 8. Number of the combinations of b_{1yw} showing the significant difference (under the same grade of wind wave).

Grade of wind wave (w)	1 L	1 S	2 L	2 S	3 L	3 S	4 L	4 S	5 L	5 S	6 L	6 S	7 L	7 S
Depth (y in meters) 50														
60														
80														
90		3			2		2		2			3		
100														
110						1				1	2			
120														
130														
140														
150						1		1			2			
Sum		3			2	2	2	1	2	1	4	3		

L : significantly larger than the other b_{1yw}
S : significantly smaller than the other b_{1yw}

$b_{1.15.4}$. The latter four coefficients were insignificant. Accordingly, it was hard to regard that the different wave grade caused the significant difference in b_{1yw}, because of the following reasons: 1) the rate of the pairs of b_{1yw} in the same depth zones showing the significant difference was very low, 2) the significant differences were mainly relating to the insignificant b_{1yw}, and 3) the presence of only one significant b_{1yw} contributing to cause the significant difference was not worthy to give much importance, for the phrase "significant at 0.05 level" means that there are 5% of the coefficients or their combinations taking larger F or t than those shown in the tables even when the dependent variable has no relation to the independent one or when the pairs of b_{1yw} from the same statistic population were compared with one another.

The t_h-catch relation is defined not only by b_{1yw} but also by b_{0yw} and the applicable catch range of the estimated equation, but the above-mentioned examination dealt only with b_{1yw}. For the purpose of showing the difference of the t_h-catch relations under the different wave grades in the same depth zones, the estimated relations were illustrated in Fig. 4. This figure showed that there were some estimated equations showing the different trends from those of the other equations in the smae depth zones. But the estimated regression coefficients in most of them were insignificant mainly because of the narrow range of the independent variable (i.e. the amount of catch). And their differences were not worthy to give any meanings. The different trends derived from the lines with the significant regression coefficient were 1) short t_h for the hauls of poor catch but longer one for the hauls of good catch than the others due to the small constant and the large coefficient in (9.4) and (11.6)*, 2) longer t_h for the hauls of poor catch than the others due to the large constant and small coefficient in (10.7),

*Hereafter the stratum of the records in the 10 × y m zone under the wave grade w was expressed as ($y.w$).

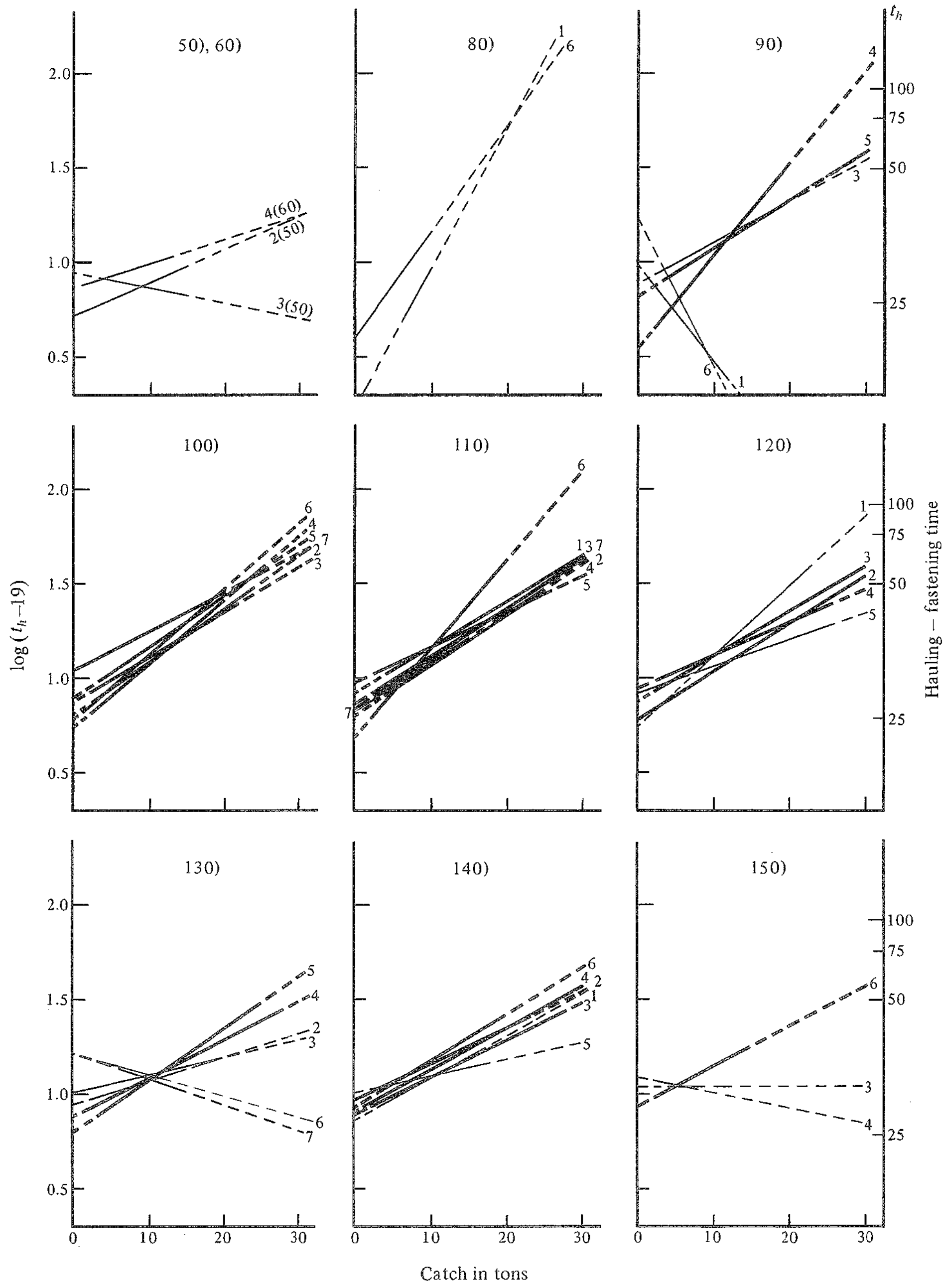

Fig. 4. The change of the estimated log(t_h - 19) – catch relation in accordance with the wave grade.

Note: The numeral with parenthesis shows the depth fished in meters. That attached to the line is the grade of wind wave.

and 3) shorter t_h for the hauls of poor catch than the others due to the small constant and the large coefficient in (12.2). Even these lines crossed to the other lines, and the hauls relating to cause these differences were not many. These facts meant that the difference in the wave grade hardly caused any notable difference in the t_h-catch relations in the same depth zones.

5.3 The difference in the catch regression according to the difference in the depth fished

It is clear that the length of the time for the fastening work has no relation to the depth fished. If the t_h-catch relation showed the difference according to the depth, the difference may be in the time for the hauling work. For finding out the probable influence of the depth on b_{1yw}, any two of b_{1yw} under the same wave grade (w) were compared with one another. As shown in Table 9, the significant difference was found in the nine pairs of b_{1yw} out of the 120 ones. And the significant differences in the seven pairs were relating to the large value of $b_{1.9.4}$ or the small value of $b_{1.9.6}$. These coefficients

Table 9 . The results of the comparison between b_{1yw} of the different depth zone (y) under the same grades of wind wave (w) through the t-test.

Grade of wind wave (w)	1		2		3		4		5		6		7	
Depth (y)	t	n	t	n	t	n	t	n	t	n	t	n	t	n
50 — 60														
50 — 80														
50 — 90					−1.16	84								
50 — 100			−0.29	168	−1.91	144								
50 — 110			0.23	153	−2.24*	197								
50 — 120			−0.21	156	−1.93	147								
50 — 130			0.14	140	−0.79	111								
50 — 140			−0.04	168	−1.65	128								
50 — 150					−0.23	60								
60 — 80														
60 — 90							−0.85	52						
60 — 100							−0.57	35						
60 — 110							−0.57	49						
60 — 120							−0.20	60						
60 — 130							−0.29	73						
60 — 140							−0.47	78						
60 — 150							0.57	20						
80 — 90	0.91	26									2.47*	36		
80 — 100											0.58	87		
80 — 110	0.74	18									0.21	56		
80 — 120	0.33	6												
80 — 130											1.59	30		
80 — 140	0.46	16									1.13	75		
80 — 150											0.80	20		

Table 9 . — (Cont'd)

Grade of wind wave (w)	1		2		3		4		5		6		7	
Depth (y)	t	n	t	n	t	n	t	n	t	n	t	n	t	n
90 — 100					−0.13	120	0.69	69	−0.25	108	−3.06**	93		
90 — 110	2.47*	38			−0.30	173	1.51	83	0.54	98	−3.07**	62		
90 — 120	1.77	26			−0.13	123	2.15*	94	0.92	108				
90 — 130					0.68	87	2.07*	107	−0.21	102	−1.37	36		
90 — 140	−1.64	36			0.15	104	2.03*	112	1.05	97	−3.46**	81		
90 — 150					0.77	36	1.08	54			−1.95	26		
100 — 110			0.22	105	−0.28	233	0.58	66	0.81	92	−0.86	113	−0.37	84
100 — 120			0.26	108	0.02	183	1.34	77	1.19	102				
100 — 130			1.11	92	1.30	147	1.17	90	0.00	96	1.31	87	1.59	66
100 — 140			0.75	120	0.52	164	1.09	95	1.27	91	0.77	132		
100 — 150					1.45	96	0.98	37			0.38	77		
110 — 120	−0.84	18	0.07	93	0.34	236	1.46	91	0.39	92				
110 — 130			1.06	77	1.61	200	1.11	104	−0.69	86	1.54	56	0.96	32
110 — 140	0.09	28	0.64	105	0.90	217	0.82	109	0.69	81	1.62	101		
110 — 150					1.55	149	1.28	51			0.67	46		
120 — 130			0.93	80	1.32	150	−0.35	115	−1.02	96				
120 — 140	0.38	16	0.54	108	0.56	167	−0.79	120	0.36	91				
120 — 150					1.35	99	0.97	62						
130 — 140			−0.52	92	−0.96	131	−0.39	133	1.13	85	−1.46	75		
130 — 150					0.40	63	0.97	75			−1.18	20		
140 — 150					1.22	80	1.35	80			0.14	65		

Note: * significant at 0.05 level ** significant at 0.01 level

Table 10. Number of the combinations of b_{1yw} showing the significant difference (in the same depth zones).

Depth (y in meters)	50		80		90		100		110		120		130		140		150	
	L	S	L	S	L	S	L	S	L	S	L	S	L	S	L	S	L	S
Grade of wind wave (w) 1					1					1								
2																		
3		1							1									
4					3							1		1		1		
5																		
6			1			4	1		1						1			
7																		
Sum		1	1		4	4	1		2	1		1		1	1	1		

L : significantly larger than the other b_{1yw}

S : significantly smaller than the other b_{1yw}

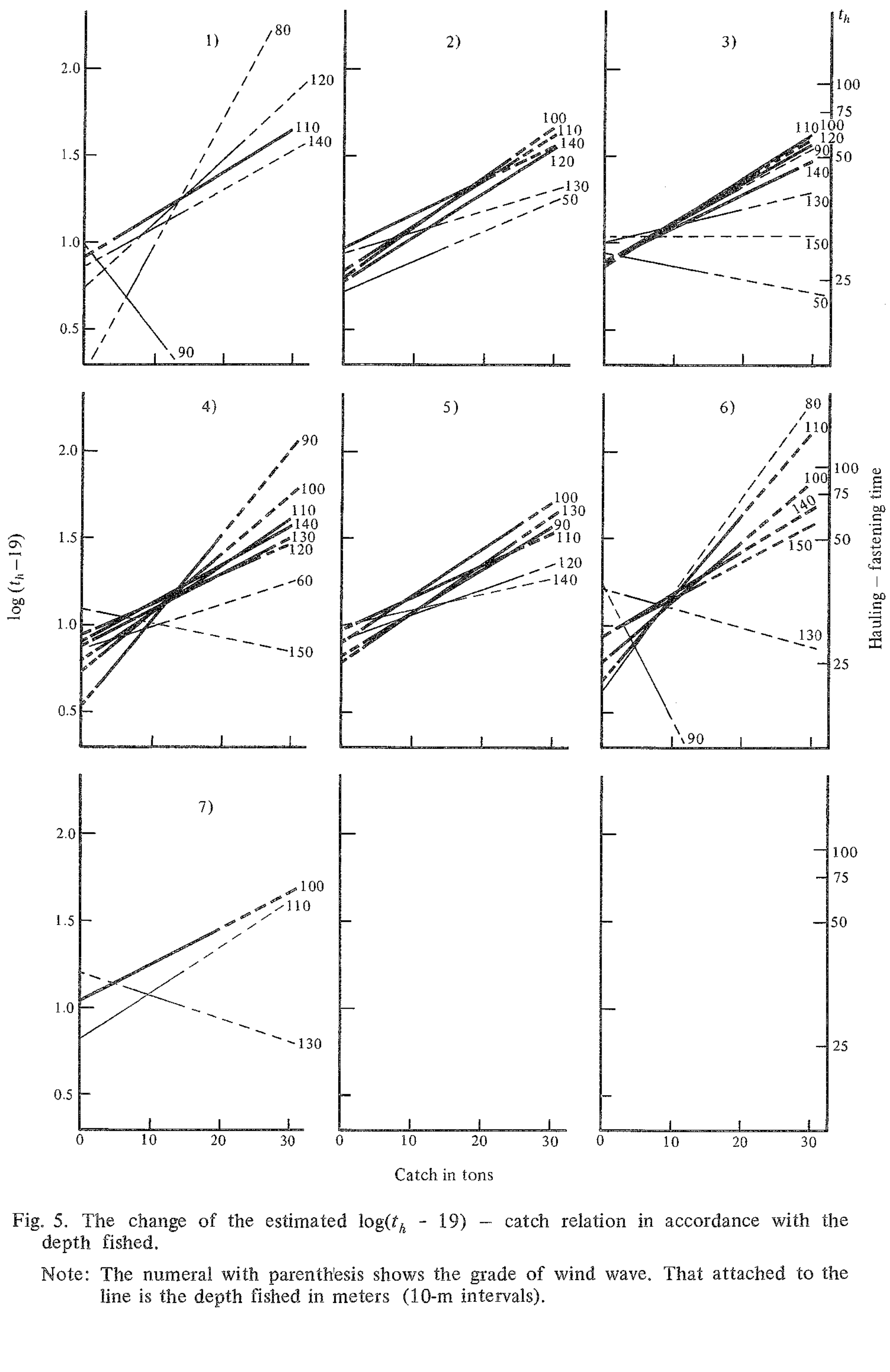

Fig. 5. The change of the estimated $\log(t_h - 19)$ – catch relation in accordance with the depth fished.

Note: The numeral with parenthesis shows the grade of wind wave. That attached to the line is the depth fished in meters (10-m intervals).

were estimated from the records of sufficiently large sample size. These facts meant that the difference in the depth hardly caused any significant differences in b_{1yw}.

The above-mentioned examinations concerned only with the difference in b_{1yw}, but t_h differs not only depending on b_{1yw} but also depending on b_{0yw}. For the purpose of finding out the difference in the t_h-catch relation due to the difference in the depth fished after eliminating the probable influence of the grade of wind wave, the t_h-catch relations under the same wave grades in the different depth zones were compared with one another in Fig. 5. This figure showed that there were some equations showing the different trend from the others under the same grade of wind wave. But the regression coefficient in most of them was insignificant, mainly because of the narrow range of the independent variable (i.e. the amount of catch). And it was hard to give any meanings on them. The different trend derived from the significant regression lines was short t_h for the hauls of poor catch but longer one for the hauls of good catch than the others due to the small constant and the large coefficient in (9.4) and (11.6). Even these lines crossed to the other lines of the same wave grade, and the hauls causing these differences were not many. These lines showed the different trend from the other lines in the same depth zones under the different wave grade as shown in Fig. 4. The trend of the change in the t_h-catch lines in accordance with the depth differed according to the wave grade. These facts meant that the difference in the depth hardly caused any notable difference in the t_h-catch relations under the wind wave of the same grade.

5.4 The comparison of the regression lines of the different depth zones under the different wave grades

The differences in the t_h-catch relations due to the difference either in the wave grade or in the depth were examined in the preceding sections. There lacked, however, the comparison among all the estimated relations with one another, in spite of the fact that most of the significant differences between the t_h-catch relations in the same depth zones or under the same wave grades were due to the presence of few strata showing the different trend from the others.

The length of the hauling-fastening time is defined by the coefficient, the constant, and the applicable catch range. The amount of catch by a haul ranged mainly from 10 to 30 tons. Accordingly, with the assistance of Fig. 6, the t_h-catch relations in all the strata were compared with one another. And the following trends were found out: 1) the lines for (9.6), (9.1), and (5.3) showed small t_h for the hauls of better catch than five tons, because of the small coefficient. But, these lines covered the catch classes from 0 to 10 tons a haul, and practically did not cause any notable difference, 2) the lines for (13.7), (13.6), (15.4), and (5.2) showed the small t_h for the hauls of good catch because of the small coefficient. But these lines covered only the classes of poor catch, 3) the lines for (8.1), (9.4), (8.6), and (11.6) showed the small t_h for the hauls of the poor catch but the large t_h for the hauls of the good catch because of the small constant and the large coefficient, but 4) it was hard to find any clear relation between the position of the points showing respective lines in the figure and the grade of wind wave, or the depth, or the combination of them.

The results of these examinations were summarized, and it may be said that the length of the hauling-fastening time increased in accordance with the amount of catch,

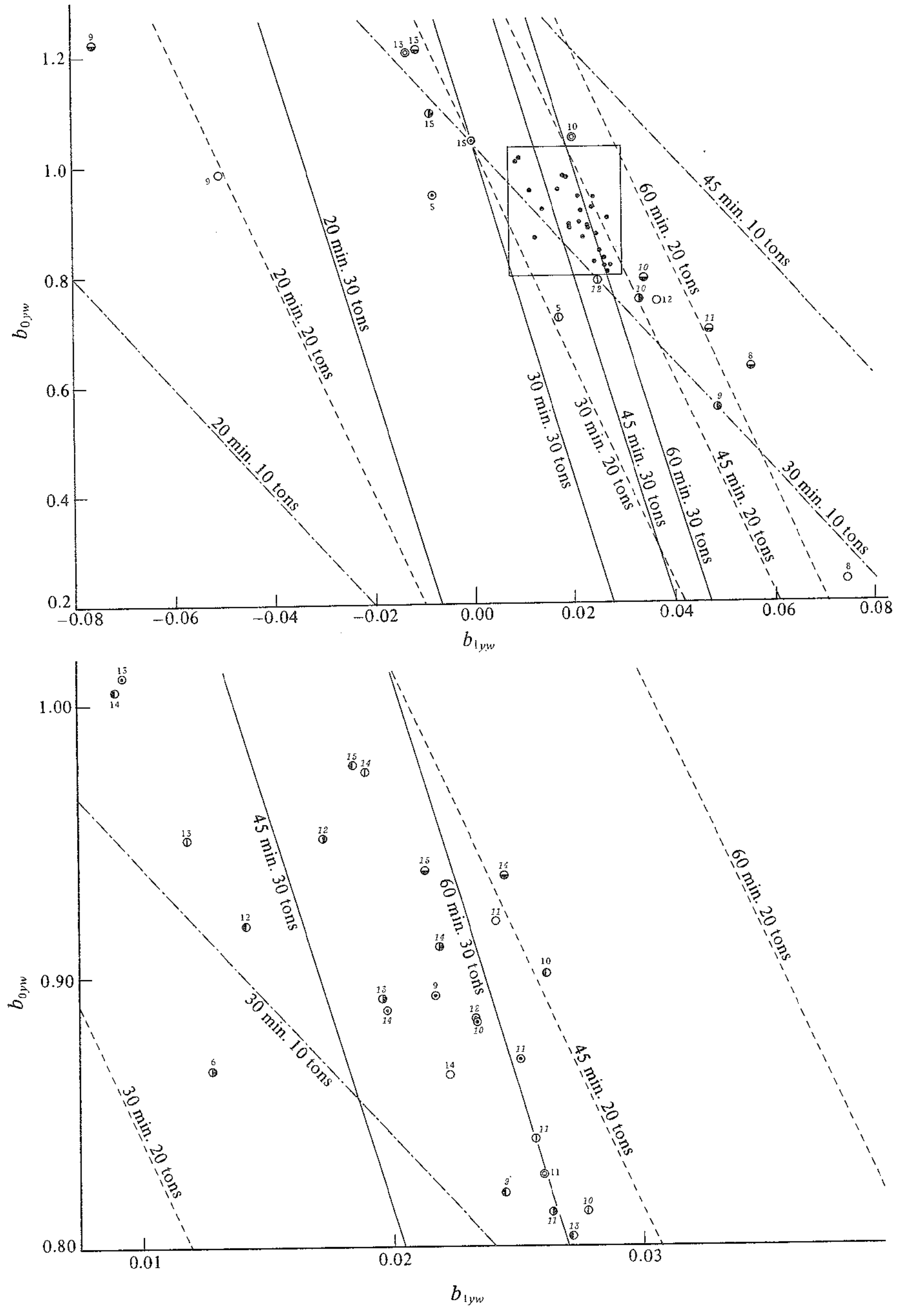

Fig. 6. The distribution of the estimated regression equations of log(t_h - 19) on the amount of catch, in respect of the constant and the coefficient.

Note
○········ the wave grade 1
◐········ the wave grade 5
⦶········ the wave grade 2
◒········ the wave grade 6
⊙········ the wave grade 3
◎········ the wave grade 7
◑········ the wave grade 4

The numeral attached to the circle is the depth zone (for example, 9 shows the 90 m zone). That printed in italic shows the equation with the significant regression coefficient.

but it was hard to find any notable difference in the influence of catch according to the grade of wind wave or the depth.

6. The regression on the depth fished after the twofold stratification of the records according to the wave grade and the amount of catch

The length of the hauling-fastening time showed the significant regression on the depth in the six wave grades out of the eight ones. But the t_h-depth relation varied according to the grade of wind wave, and it was hard to find its change in accordance with the grade of wind wave. The length of the hauling-fastening time changed in accordance with the amount of catch, and the amount of catch showed the bathymetric difference. Accordingly, it is necessary to examine the t_h-depth relation after eliminating the influence of the probable bathymetric difference of the catch and to examine the change relating to either the amount of catch or the grade of wind wave. And the regression equations of t_h on the depth were estimated after the twofold stratification of the records according to the grade of wind wave and the amount of catch, and the estimated regression lines were compared with one another.

6.1 The significance of the regression on the depth fished

The wind wave during the season varied from the grade 1 to 9, but the boat could not fish on the days in the grade 9, and the number of the records under the grade 8 was not sufficiently large to be stratified according to the amount of catch. The records in these wave grades were excluded from the further examinations. The amount of catch by a haul varied from 0 to 35 tons. The records under respective wave grades were stratified into the catch-classes of 1-ton intervals, but some of the strata had not sufficient samples to estimate the regression line, and they were also excluded from the further examinations. As shown in Table 11, the linear regression equation in each of

Table 11. The linear regression equations of the hauling-fastening time (t_h in min.) on the depth of the fishing ground (y in m) after the twofold stratification of the records according to the catch (x in tons) and the grade of wind wave (w).

$$\log(t_h - 19) = c_{0xw} + c_{1xw}y$$

Grade of wind wave (w)	1				2				3				4			
	c_{0x1}	c_{1x1}	F_0	n_2	c_{0x2}	c_{1x2}	F_0	n_2	c_{0x3}	c_{1x3}	F_0	n_2	c_{0x4}	c_{1x4}	F_0	n_2
Catch (x tons) 2					0.8847	0.0015	0.77	8	0.9708	0.0008	0.27	11	0.9493	0.0008	0.89	16
3	1.0414	0.0000	0.00	4	−0.1205	0.0078	0.93	15	0.8487	0.0015	0.13	24	−0.0870	0.0081	4.44	15
4	−0.5415	0.0125	1.38	5	0.9323	0.0004	0.01	29	1.0363	−0.0003	0.01	32	1.3739	−0.0028	0.84	24
5	−0.3744	0.0129	0.20	6	0.6313	0.0031	0.11	38	1.1654	−0.0008	0.18	44	0.0853	0.0077	8.08**	33
6					1.2737	−0.0020	0.46	25	1.0706	0.0001	0.01.	41	1.4385	−0.0034	1.47	21
7					1.2613	−0.0020	0.19	16	1.4178	−0.0031	2.11	52	0.1022	0.0069	5.28*	26
8	−0.2314	0.0098	1.83	5	1.3992	−0.0021	0.41	11	1.0650	0.0000	0.000006	48	0.9133	0.0010	0.09.	24
9									0.0593	0.0074	1.71	16	−0.6090	0.0143	3.96	6
10	2.6556	−0.0144	2.04	5	0.8814	0.0015	0.10	19	0.4042	0.0054	2.18	41	1.2292	−0.0018	0.20	23
11					1.0414	0.0000	0.00	5	1.7362	−0.0058	0.70	12	2.0243	−0.0070	3.57	5
12	−0.5039	0.0128	2.28	5					0.9366	0.0008	0.02	18	0.8785	0.0015	1.30	10
13					1.6908	−0.0053	4.80	8	1.2511	−0.0016	0.12	26	1.4489	−0.0030	1.94	17
14					0.6228	0.0044	1.83	5	1.2710	−0.0028	0.24	14				
15					0.6743	0.0039	0.33	17	1.8976	−0.0061	5.05*	33	1.7974	−0.0053	3.35	24
17									1.1158	0.0039	0.65	9	2.0172	−0.0059	0.92	4
18									1.6628	−0.0021	0.14	8	1.9523	−0.0042	0.86	5
20					1.2520	0.0018	0.28	6	1.4250	−0.0003	0.01	13	1.3789	0.0003	0.01	8
25					2.9460	−0.0135	2.67	4	2.2599	−0.0062	1.16	5	0.1286	0.0114	2.44	7

Grade of wind wave (w)		5				6				7			
		c_{0x5}	c_{1x5}	F_0	n_2	c_{0x6}	c_{1x6}	F_0	n_2	c_{0x7}	c_{1x7}	F_0	n_2
Catch (x tons)	2	1.0414	0.0000	0.00	4	1.0414	0.0000	0.00	3				
	3	0.8473	0.0006	0.01	18	0.4030	0.0052	0.77	12	7.8561	−0.0667	4.43	5
	4	0.6635	0.0035	1.44	26	0.6806	0.0024	0.06	19	6.6977	−0.0549	2.22	5
	5	1.1585	−0.0016	0.44	49	0.7373	0.0027	1.13	33	0.1521	0.0094	1.16	8
	6	0.7591	0.0024	0.29	23	−0.3056	0.0101	3.09	15	1.2066	−0.0002	0.001	7
	7	1.5094	−0.0038	2.46	28	0.1464	0.0096	3.31	14	4.9070	−0.0358	0.51	4
	8	1.7042	−0.0053	2.06	28	0.8613	0.0015	0.14	22	1.5451	−0.0040	1.58	7
	9	−0.6346	0.0114	0.95	4	1.0414	0.0000	0.00	8	1.8137	−0.0070	0.20	3
	10	0.3256	0.0063	1.50	15	0.9133	0.0019	0.27	19	1.1405	−0.0004	0.02	13
	11	1.0414	0.0000	0.00	6	0.6527	0.0025	0.13	7				
	12	2.6733	−0.0139	2.34	8								
	13	0.8843	0.0025	1.21	17	1.0742	0.0021	0.27	21	3.1980	−0.0188	2.40	12
	14	0.6480	0.0036	0.14	8								
	15	0.8265	0.0035	0.35	8	0.8216	0.0040	0.41	9				
	17												
	18	1.4041	0.0003	0.02	4								
	20	0.7745	0.0051	0.60	6	1.5914	−0.00002	0.00002	6				
	25	1.7969	−0.0030	0.71	5								

Note : df . . . $n_1 = 1$ n_2 = the value shown in the table
* significant at 0.05 level ** significant at 0.01 level

the 94 strata was estimated. The estimated coefficient varied according to the catch classes and the wave grades. The rate of the strata taking the positive coefficient varied according to the wave grade. The coefficient was significantly positive in the two strata but significantly negative in one of the strata. That in the 54 strata took the insignificantly positive value, but that in the 37 strata took the insignificantly negative one. These facts meant that the difference in the depth hardly caused any notable difference in the length of the hauling-fastening time. And the significant depth regression found in the multiple linear regression equations and in the linear one before the stratification of the records according to the amount of catch may be either due to the additional effect of the insignificant regression or due to the different amount of catch relating to the depth.

6.2 The difference of the depth regression according to the wave grade

The examinations in the preceding section showed that the rate of the strata taking the positive coefficient varied according to the wave grade, although most of the estimated regression coefficients were insignificant. This fact suggested the possibility of the depth regression differing according to the wave grade. For clarifying this point, the estimated regression coefficients in the same catch-classes under the different wave grades were compared with one another. As shown in Table 12, the significant difference of c_{1xw} was found in the 19 pairs out of the 219 ones. And all the significant differences in the 3-ton class were due to the small value of $c_{1.3.7}$; all those in the 4-ton class were due to the small value of $c_{1.4.7}$; all those in the 5-ton class were due to the large value of $c_{1.5.4}$; all those in the 6-ton class were due to the large value of $c_{1.6.6}$; all those in the 7-ton class were due to either the large value of $c_{1.7.4}$ or $c_{1.7.6}$ or the small value of $c_{1.7.3}$ or $c_{1.7.5}$; and all those in the 11-ton class were due to the small value of $c_{1.11.4}$. The low rate of the pairs showing the significant difference and the difficulty in finding out the relation between x or w to the distribution of the strata indebted to cause the

Table 12. The results of the comparison between c_{1xw} under the different grades of wind wave (w) through the t-test.

Catch class (x)	2		3		4		5		6		7		8		9		10	
Grade of wind wave (w)	t	n	t	n	t	n	t	n	t	n	t	n	t	n	t	n	t	n
1 − 2			−0.77	19	1.36	34	0.51	44					1.74	16			−1.75	24
1 − 3			−0.28	28	1.65	37	0.92	50					2.13*	53			−2.23*	46
1 − 4			−1.34	19	2.08*	29	0.26	39					1.16	29			−1.39	28
1 − 5			−0.07	22	1.22	31	0.73	55					1.91	33			−1.96	20
1 − 6			−0.64	16	0.73	24	0.55	39					1.00	27			−1.81	24
1 − 7			2.77*	9	1.67	10	0.11	14					1.63	12			−1.55	18
2 − 3	0.31	19	0.73	39	0.14	61	1.12	82	−0.83	66	0.24	68	−0.57	59			−0.60	60
2 − 4	0.41	24	−0.04	30	0.63	53	−1.13	71	0.35	46	−1.60	42	−0.52	35			0.52	42
2 − 5	0.41	12	0.72	33	−0.64	55	1.20	87	−0.84	48	0.36	44	0.50	39			−0.67	34
2 − 6	0.66	11	0.26	27	−0.20	48	0.10	71	−1.99	40	−1.61	30	−0.55	33			−0.06	38
2 − 7			1.94	20	1.82	34	−0.34	46	−0.27	32	1.07	20	0.36	18			0.26	32
3 − 4	0.00	27	−1.12	39	0.55	56	−2.60*	77	1.44	62	−2.84**	78	−0.30	72	−0.72	22	1.34	64
3 − 5	0.23	15	0.12	42	−0.87	58	0.24	93	−0.66	64	0.22	80	1.46	76	−0.35	20	−0.15	56
3 − 6	0.37	14	−0.52	36	−0.30	51	−1.12	77	−2.49*	56	−2.87**	66	−0.41	70	0.73	24	0.67	60
3 − 7			3.07**	29	2.10*	37	−0.78	52	0.09	48	1.33	56	0.79	55	0.32	19	0.65	54
4 − 5	0.28	20	1.04	33	−1.48	50	2.54*	82	−1.13	44	2.80**	54	1.28	52	0.23	10	−1.28	38
4 − 6	0.50	19	0.43	27	−0.59	43	1.34	66	−2.25*	36	−0.49	40	−0.10	46	1.79	14	−0.69	42
4 − 7			2.61*	20	2.25*	29	−0.09	41	−0.45	28	1.38	30	0.58	31	0.58	9	−0.17	36
5 − 6	0.00	7	−0.54	30	0.13	45	−1.18	82	−1.10	38	−2.68*	42	−1.25	50	1.08	12	0.71	34
5 − 7			1.91	23	2.44*	31	−0.53	57	0.26	30	1.15	32	−0.14	35	0.39	7	0.75	28
6 − 7			2.06	17	1.60	24	−0.39	41	0.82	22	1.11	18	0.58	29	0.83	11	0.30	32

Catch class (x)	11		12		13		14		15		17		18		20		25	
Grade of wind wave (w)	t	n	t	n	t	n	t	n	t	n	t	n	t	n	t	n	t	n
1 − 2																		
1 − 3			1.27	23														
1 − 4			1.60	15														
1 − 5			2.11	13														
1 − 6																		
1 − 7																		
2 − 3	0.61	17			−0.34	34	0.72	19	1.63	50					0.38	19	−0.51	9
2 − 4	2.31*	10			−0.53	25			1.40	41					0.35	14	−1.15	11
2 − 5	0.00	11			−1.62	25	0.07	13	0.04	25					−0.46	12	−0.77	9
2 − 6	−0.28	12			−1.01	29			−0.01	26					0.32	12		
2 − 7					1.19	20												
3 − 4	0.08	17	−0.10	28	0.24	43			−0.20	57	1.18	13	0.29	13	−0.13	21	−1.76	12
3 − 5	−0.63	18	1.48	26	−0.72	43	−0.61	22	−1.77	41			−0.40	12	−0.64	19	−0.46	10
3 − 6	−0.84	19			−0.56	47			−1.91	42					−0.05	19		
3 − 7					0.98	38												
4 − 5	−2.43*	11	1.73	18	−1.76	34			−1.57	32			−0.92	9	−0.72	14	−1.82	12
4 − 6	−0.68	12			−1.13	38			−1.62	33					0.07	14		
4 − 7					1.58	29												
5 − 6	−0.29	13			0.09	38			−0.06	17					0.60	12		
5 − 7					2.03	29												
6 − 7					1.62	33												

Note : * significant at 0.05 level ** significant at 0.01 level

significant difference hardly suggested the possibility of c_{1xw} differing according to the wave grade.

The above-mentioned examinations concerned only with the difference in the c_{1xw}. For the purpose of giving consideration paying attention to the value of c_{0xw} and the applicable catch range of the estimated equations, the estimated lines were illustrated in Fig. 7. But it was hard to find any clear trend of the change of the t_h-depth relation in accordance with the grade of wind wave or in accordance with both the grade of wind

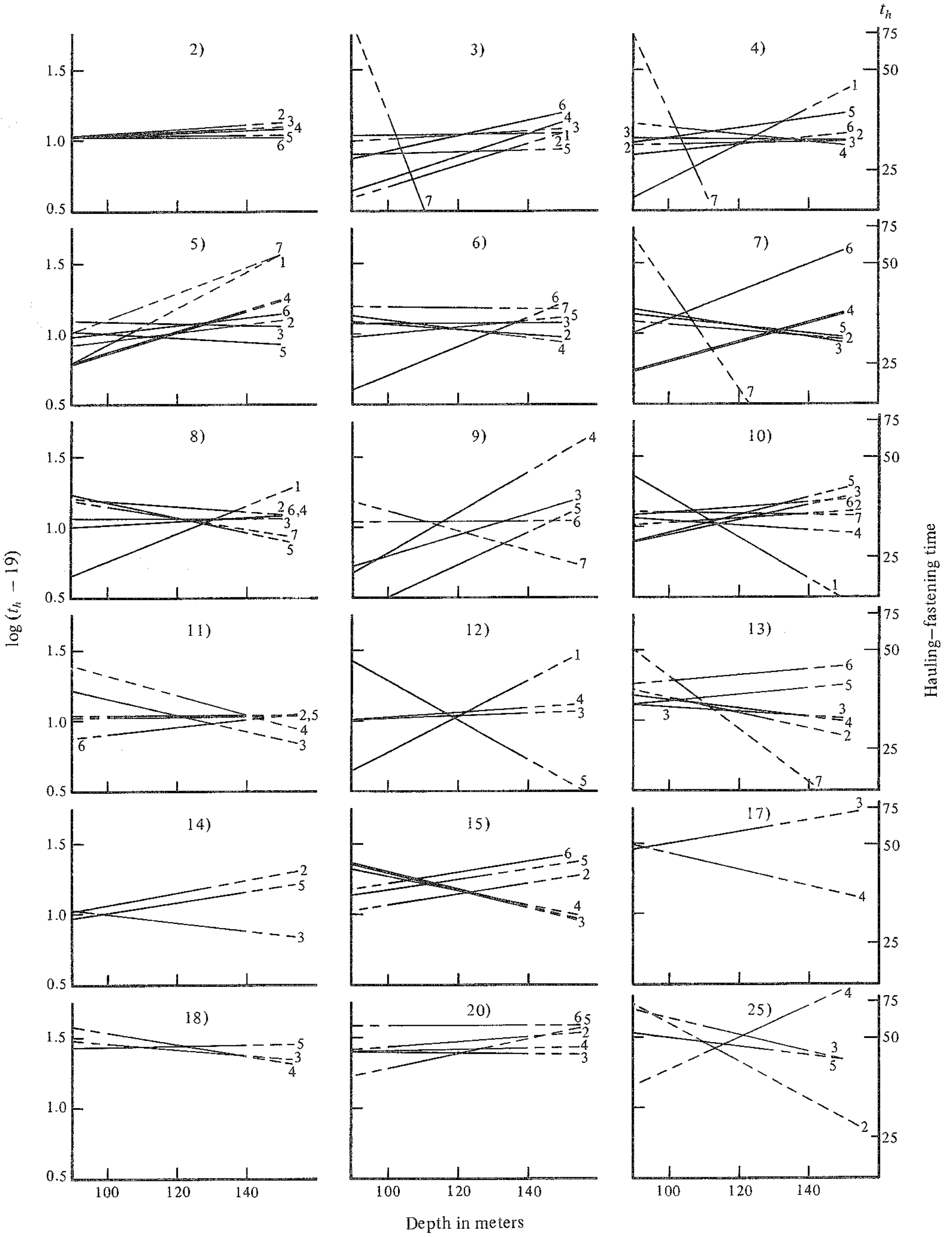

Fig. 7. The change of the estimated $\log(t_h - 19)$ – depth relation in accordance with the grade of wind wave.

Note: The numeral attached to the line is the grade of wind wave.

Table 13. Number of the combinations of c_{1xw} showing the significant difference (under the same wave grade).

Grade of wind wave (w)	1		2		3		4		5		6		7	
	L	S	L	S	L	S	L	S	L	S	L	S	L	S
Catch-class (x in tons) 2														
3	1				1		1							3
4	1				1		1	1	1					3
5						1	2			1				
6						1		1			2			
7						2	2			2	2			
8	1					1								
9														
10		1			1									
11			1					2	1					
12														
13														
14														
15														
17														
18														
20														
25														
Sum	3	1	1		3	5	6	4	2	3	4			6

L : significantly larger than the other c_{1xw}
S : significantly smaller than the other c_{1xw}

wave and the amount of catch. Some of the lines, especially those under the wave grade 7, were estimated from the records distributing in the narrow depth range; they were excluded. But the estimated lines within the same catch-classes showed a large variation, and it was hard to find any clear trend of the change of the t_h-depth relations according to the wave grade. These results meant that the different wave grade hardly caused any notable difference in the t_h-depth relation.

6.3 The difference of the depth regression according to the catch class

It is probable that the depth regression of the length of the hauling-fastening time differs according to the amount of catch, for the catch is very good and the resistance of hauling up the net differs according to the amount of catch in the cod end. This possibility was examined by comparing c_{1xw} of the different catch classes under the same wave grade with one another. As shown in Table 14, the difference between c_{1xw} of the different x under the same w was significant in the 42 pairs out of the 644 ones. The significant difference in the 24 pairs out of the 42 ones was in the wave grade 4, mainly relating to the large value of $c_{1.3.4}$, $c_{1.5.4}$, $c_{1.7.4}$, $c_{1.9.4}$, $c_{1.25.4}$, or the small value of $c_{1.4.4}$, $c_{1.6.4}$, $c_{1.13.4}$, or $c_{1.15.4}$. All the significant differences in the wave grade 2 were due to the small value of $c_{1.13.2}$; more than a half of those in the wave

Table 14. The results of the comparison between c_{1xw} of the different catch classes (x) through the t-test.

Grade of wind wave (w)	1		2		3		4		5		6		7	
Catch class (x)	t	n	t	n	t	n	t	n	t	n	t	n	t	n
2 — 3			−0.65	23	−0.14	35	−1.80	31	−0.03	22	−0.51	15		
2 — 4			0.17	37	0.20	43	1.08	40	−0.33	30	−0.19	22		
2 — 5			−0.27	46	0.39	55	−1.67	49	0.11	53	−0.40	36		
2 — 6			−0.78	33	0.34	52	1.27	37	−0.16	27	−0.88	18		
2 — 7			0.61	24	0.81	63	−1.54	42	0.33	32	−0.94	17		
2 — 8			0.90	19	0.21	59	−0.05	40	0.35	32	−0.17	25		
2 — 9					−0.84	27	−2.85**	22	−0.59	8	0.00	11		
2 — 10			0.00	27	−0.68	52	0.58	39	−0.39	19	−0.24	22		
2 — 11			0.70	13	0.89	23	2.46*	21	0.00	10	−0.26	10		
2 — 12					0.00	29	−0.46	26	0.63	12				
2 — 13			2.01*	16	0.34	37	1.73	33	−0.37	21	−0.34	24		
2 — 14			−0.86	13	0.50	25			−0.20	12				
2 — 15			−0.32	25	1.76	44	2.07*	40	−0.33	12	−0.46	12		
2 — 17					−0.68	20	1.80	20						
2 — 18					0.60	19	1.66	21	−0.09	8				
2 — 20			−0.09	14	0.27	24	0.23	24	−0.68	10	0.004	9		
2 — 25			1.58	12	1.52	16	−2.23*	23	0.53	9				
3 — 4	−1.23	9	0.94	44	0.32	56	2.27*	39	−0.46	44	0.24	31	−0.24	10
3 — 5	−0.54	10	0.66	53	0.52	68	0.09	48	0.37	67	0.46	45	−2.80*	13
3 — 6			1.35	40	0.42	65	2.49*	36	−0.24	41	−0.58	27	−2.65*	12
3 — 7			1.09	31	0.94	76	0.25	41	0.76	46	−0.01	26	−0.54	9
3 — 8	−1.36	9	1.07	26	0.36	72	1.40	39	0.86	46	0.54	34	−2.74*	12
3 — 9					−0.80	40	−0.81	21	−0.92	22	0.54	20	−1.37	8
3 — 10	1.53	9	0.69	34	−0.60	65	1.81	38	−0.71	33	0.50	31	−3.36**	18
3 — 11			0.65	20	0.98	36	1.22	20	0.06	24	0.28	19		
3 — 12	−1.42	9			0.10	42	1.25	25	1.41	26				
3 — 13			0.94	23	0.46	50	2.32*	32	−0.29	35	0.44	33	−1.73	17
3 — 14			0.27	20	0.61	38			−0.27	26				
3 — 15			0.36	32	1.59	57	2.67*	39	−0.28	26	0.13	21		
3 — 17					−0.35	33	1.21	19						
3 — 18					0.46	32	1.42	20	0.03	22				
3 — 20			0.48	21	0.33	37	1.24	23	−0.27	24	0.54	18		
3 — 25			0.46	19	0.84	29	−0.33	22	0.34	23				
4 — 5	−0.01	11	−0.58	67	0.14	76	−2.31*	57	1.17	75	−0.03	52	−2.08	13
4 — 6			0.49	54	−0.14	73	0.14	45	0.21	49	−0.65	34	−1.94	12
4 — 7			0.39	45	0.76	84	−2.15*	50	1.89	54	−0.64	33	−0.31	9
4 — 8	0.21	10	0.39	40	−0.10	80	−0.80	48	1.80	54	0.09	41	−1.94	12
4 — 9					−1.31	48	−2.80**	30	−1.06	30	0.20	27	−0.96	8
4 — 10	1.83	10	−0.17	48	−1.16	73	−0.20	47	−0.51	41	0.05	38	−2.44*	18
4 — 11			0.05	34	0.82	44	0.46	29	0.61	32	−0.01	26		
4 — 12	−0.02	10			−0.18	50	−1.03	34	2.49*	34				
4 — 13			0.55	37	0.24	58	0.05	41	0.25	43	0.03	40	−1.19	17

Table 14 . — (Cont'd)

Grade of wind wave (w)	1		2		3		4		5		6		7	
Catch class(x)	t	n	t	n	t	n	t	n	t	n	t	n	t	n
4 — 14			−0.45	34	0.43	46			−0.01	34				
4 — 15			−0.44	46	1.31	65	0.58	48	0.00	34	−0.14	28		
4 — 17					−0.57	41	0.37	28						
4 — 18					0.21	40	0.22	29	0.57	30				
4 — 20			−0.16	35	0.00	45	−0.63	32	−0.16	32	0.20	25		
4 — 25			0.39	33	0.55	37	−1.84	31	1.07	31				
5 — 6			1.13	63	−0.41	85	2.67	54	−0.82	72	−1.38	48	0.84	15
5 — 7			0.90	54	0.79	96	0.20	59	0.61	77	−1.36	47	1.19	12
5 — 8	0.11	11	0.90	49	−0.31	92	1.60	57	0.85	77	0.27	55	1.50	15
5 — 9					−1.79	60	−0.96	39	−1.59	53	0.38	41	0.93	11
5 — 10	0.94	11	0.27	57	−1.57	85	2.01*	56	−1.48	64	0.18	52	1.11	21
5 — 11			0.41	43	0.95	56	1.14	38	−0.20	55	0.03	40		
5 — 12	0.003	11			−0.33	62	1.15	43	1.84	57				
5 — 13			0.88	46	0.18	70	2.19*	50	−0.85	66	0.12	54	1.73	20
5 — 14			−0.16	43	0.44	58			−0.66	57				
5 — 15			−0.11	55	1.51	77	2.54*	57	−0.63	57	−0.22	42		
5 — 17					−0.84	53	1.16	37						
5 — 18					0.19	52	1.37	38	−0.26	53				
5 — 20			0.16	44	−0.12	57	1.17	41	−0.48	55	0.41	39		
5 — 25			0.51	42	0.67	49	−0.37	40	0.17	54				
6 — 7			0.00	41	1.28	93	−2.45*	47	1.32	51	0.06	29	1.03	11
6 — 8			0.02	36	0.05	89	−0.99	45	1.35	51	1.28	37	0.62	14
6 — 9					−1.86	57	−2.84**	27	−0.93	27	0.90	23	0.33	10
6 — 10			−0.66	44	−1.48	82	−0.33	44	−0.58	38	1.24	34	0.03	20
6 — 11			−0.36	30	1.43	53	0.37	26	0.28	29	0.76	22		
6 — 12					−0.17	59	−1.15	31	1.92	31				
6 — 13			0.49	33	0.45	67	−0.10	38	−0.02	40	1.06	36	1.44	19
6 — 14			−1.08	30	0.78	55			−0.12	31				
6 — 15			−0.90	42	2.48*	74	0.44	45	−0.13	31	0.65	24		
6 — 17					−1.15	50	0.27	25						
6 — 18					0.58	49	0.12	26	0.26	27				
6 — 20			−0.65	31	0.16	54	−0.73	29	−0.19	29	0.94	21		
6 — 25			0.51	29	1.51	46	−1.30	28	0.62	28				
7 — 8			0.02	27	−1.12	100	1.34	50	0.35	56	1.26	36	−0.97	11
7 — 9					−2.21*	68	−1.08	32	−2.08*	32	0.97	22	−0.46	7
7 — 10			−0.54	35	−2.11*	93	1.78	49	−2.00	43	1.23	33	−1.30	17
7 — 11			−0.29	21	0.48	64	1.15	31	−0.63	34	0.77	21		
7 — 12					−0.77	70	1.05	36	1.54	36				
7 — 13			0.40	24	−0.33	78	2.11*	43	−1.63	45	1.09	35	−0.48	16
7 — 14			−0.85	21	−0.06	66			−1.04	36				
7 — 15			−0.74	33	0.77	85	2.48*	50	−1.11	36	0.64	23		
7 — 17					−1.10	61	1.15	30						
7 — 18					−0.13	60	1.34	31	−0.71	32				

Table 14. — (Cont'd)

Grade of wind wave (*w*)	1		2		3		4		5		6		7	
Catch class(*x*)	*t*	*n*	*t*	*n*	*t*	*n*	*t*	*n*	*t*	*n*	*t*	*n*	*t*	*n*
7 — 20			−0.52	22	−0.61	65	1.09	34	−0.83	34	1.00	20		
7 — 25			0.42	20	0.33	57	−0.47	33	−0.13	33				
8 — 9					−1.71	64	−1.80	30	−1.83	32	0.17	30	0.21	10
8 — 10	1.98	10	0.59	30	−1.42	89	0.55	47	−1.87	43	−0.07	41	−0.79	20
8 — 11			−0.45	16	1.19	60	0.60	29	−0.64	34	−0.13	29		
8 — 12	−0.26	10			−0.17	66	−0.09	34	1.09	36				
8 — 13			0.57	19	0.39	74	0.79	41	−1.50	45	−0.10	43	1.28	19
8 — 14			−1.22	16	0.66	62			−1.02	36				
8 — 15			−0.80	28	1.87	81	1.20	48	−1.03	36	−0.33	31		
8 — 17					−0.77	57	0.56	28						
8 — 18					0.35	56	0.57	29	−0.71	32				
8 — 20			−0.74	17	0.08	61	0.11	32	−0.73	34	0.18	28		
8 — 25			0.62	15	0.86	53	−0.99	31	−0.27	33				
9 — 10					0.32	57	2.11*	29	0.47	19	−0.24	27	−0.46	16
9 — 11					1.43	28	1.61	11	1.04	10	−0.29	15		
9 — 12					0.81	34	2.09	16	1.69	12				
9 — 13					1.26	42	3.10**	23	1.25	21	−0.34	29	0.45	15
9 — 14					1.26	30			0.54	12				
9 — 15					2.35*	49	3.38**	30	0.66	12	−0.50	17		
9 — 17					0.34	25	1.56	10						
9 — 18					0.77	24	1.85	11	0.93	8				
9 — 20					1.03	29	1.90	44	0.36	10	0.004	14		
9 — 25					0.89	21	0.25	13	1.19	9				
10 — 11			0.20	24	1.50	35	0.40	28	0.71*	21	−0.08	26		
10 — 12	−2.04	10			0.70	59	−0.57	33	2.11*	23				
10 — 13			0.78	27	1.19	67	0.23	40	0.67	32	−0.03	40	1.71	25
10 — 14			−0.37	24	1.28	55			0.27	23				
10 — 15			−0.30	36	2.20*	74	0.65	47	0.30	23	−0.30	28		
10 — 17					0.17	50	0.34	27						
10 — 18					0.71	49	0.26	28	0.68	19				
10 — 20			−0.04	25	0.89	54	−0.31	31	0.08	21	0.25	25		
10 — 25			0.52	23	0.90	46	−1.26	30	1.00	20				
11 — 12					−0.72	30	−2.27*	15	1.14	14				
11 — 13			2.26*	13	−0.52	38	−0.71	22	−0.67	23	0.06	28		
11 — 14			−1.39	10	−0.33	26			−0.34	14				
11 — 15			−0.44	22	0.05	45	−0.24	29	−0.55	14	−0.16	16		
11 — 17					−0.99	21	−0.15	9						
11 — 18					−0.33	20	−0.42	10	−0.15	10				
11 — 20			−0.54	11	−0.73	25	−1.34	13	−0.96	12	0.27	13		
11 — 25			2.39*	9	0.03	17	−1.89	12	0.89	11				
12 — 13					0.33	44	1.64	27	−2.21*	25				
12 — 14					0.44	32			−1.30	16				

Table 14 . — (Cont'd)

Grade of wind wave (w)	1		2		3		4		5		6		7	
Catch class (x)	t	n	t	n	t	n	t	n	t	n	t	n	t	n
12 — 15					1.19	51	1.91	34	−1.40	16				
12 — 17					−0.31	27	1.63	14						
12 — 18					0.25	26	1.52	15	−1.14	12				
12 — 20					0.15	31	0.43	18	−0.95	14				
12 — 25					0.49	23	−1.72	17	−0.85	13				
13 — 14			−2.39*	13	0.17	40			−0.15	25				
13 — 15			−0.90	25	0.83	59	0.63	41	−0.19	25	−0.28	30		
13 — 17					−0.61	35	0.51	21						
13 — 18					0.05	34	0.27	22	0.58	21				
13 — 20			−1.69	14	−0.19	39	−0.97	25	−0.37	23	0.34	27		
13 — 25			0.96	12	0.35	31	−2.41*	24	1.29	22				
14 — 15			0.05	22	0.60	47			0.01	16				
14 — 17					−0.70	23								
14 — 18					−0.06	22			0.30	12				
14 — 20			0.56	11	−0.35	27			−0.09	14				
14 — 25			1.47	9	0.24	19			0.58	13				
15 — 17					−1.88	42	0.09	28						
15 — 18					−0.65	41	−0.20	29	0.47	12				
15 — 20			0.23	23	−1.38	46	−1.34	32	−0.15	14	0.47	15		
15 — 25			0.54	21	0.01	38	−2.51*	31	0.90	13				
17 — 18					0.80	17	−0.22	9						
17 — 20					0.70	22	−1.02	12						
17 — 25					1.23	14	−1.70	11						
18 — 20					−0.27	21	−0.91	13	−0.74	10				
18 — 25					0.49	13	−1.81	12	0.80	9				
20 — 25			1.22	10	0.76	18	−1.61	15	1.09	11				

Note : * significant at 0.05 level ** significant at 0.01 level

3 were due to the small value of $c_{1.15.3}$; most of those in the wave grade 5 were due to the small value of $c_{1.12.5}$; and most of those in the wave grade 7 were due to the small value of $c_{1.3.7}$.

The above-mentioned examination concerned only with c_{1xw}. For the purpose of finding out the change of the t_h-depth relation in accordance with the amount of catch, the values of log $(t_h - 19)$ at the 100 m, 120 m, and 140 m zones were estimated from respective regression equations of log $(t_h - 19)$ on the depth. And those out of the applicable range of respective equations were excluded. Then, the linear regression of the estimated log $(t_h - 19)$ on the amount of catch was examined. As shown in Table 16, the hauling-fastening time at respective depth zones under respective grades of wind wave except both of the extremes increased in accordance with the amount of

Table 15. Number of the combinations of c_{1xw} showing the significant difference (in the same catch class).

Catch class (x in tons)		2 L	2 S	3 L	3 S	4 L	4 S	5 L	5 S	6 L	6 S	7 L	7 S	8 L	8 S	9 L	9 S	10 L	10 S
Grade of wind wave (w)	1																		
	2	1																	
	3									1			2			2		2	
	4	2	2	4			4	4			3	4				6			2
	5					1							1			1		1	
	6																		
	7				4		1	1		1				1				2	
Sum		3	2	4	4	1	5	5		2	3	4	3	1		9		5	2

Catch class (x in tons)		11 L	11 S	12 L	12 S	13 L	13 S	14 L	14 S	15 L	15 S	17 L	17 S	18 L	18 S	20 L	20 S	25 L	25 S
Grade of wind wave (w)	1																		
	2	2					3	1											1
	3										3								
	4		2	1			5				6							3	
	5				3	1													
	6																		
	7																		
Sum		2	2	1	3	1	8	1			9							3	1

L : significantly larger than the other c_{1xw}
S : significantly smaller than the other c_{1xw}

Table 16. The estimated regression equations of t' on the amount of catch (x in tons), for the purpose of examining the change of the $\log(t_h-19)$—depth relation in accordance with the amount of catch.

Depth (y in m)		100				120				140			
		a_0	a_1	F_0	n_2	a_0	a_1	F_0	n_2	a_0	a_1	F_0	n_2
Grade of wind wave (w)	1	0.8842	0.0024	0.008	4	0.9952	−0.0019	0.06	3	1.1160	−0.0071	0.03	3
	2	0.8156	0.0273	27.26**	12	0.8960	0.0194	26.16**	12	0.8988	0.0239	22.27**	9
	3	0.8793	0.0235	12.77**	15	0.8837	0.0230	19.82**	16	0.9477	0.0150	10.69**	14
	4	0.7473	0.0341	24.31**	13	0.8585	0.0252	63.75**	15	0.9008	0.0251	19.11**	13
	5	0.8125	0.0252	11.19**	14	0.8641	0.0227	22.60**	15	0.9082	0.0176	3.37	12
	6	0.7826	0.0326	16.91**	11	0.8763	0.0292	16.33**	11	0.9837	0.0249	7.57*	10
	7	1.1435	0.0059	0.34	7	—	—	—	—	—	—	—	—

Note : The value of t' of respective depth zones used for the estimation of the regression equation was calculated from the estimated regression equation of $\log(t_h-19)$ on the depth fished shown in Table 11.

catch, in spite of the fact that most of the t_h-depth relations were insignificant. These results meant that the hauling-fastening time got longer in accordance with the amount of catch, but the depth had no relation to it.

6.4 The comparison of the depth regressions in the different catch class under the different wave grade

The fastening work is done on the surface, and it is clear that the difference in the

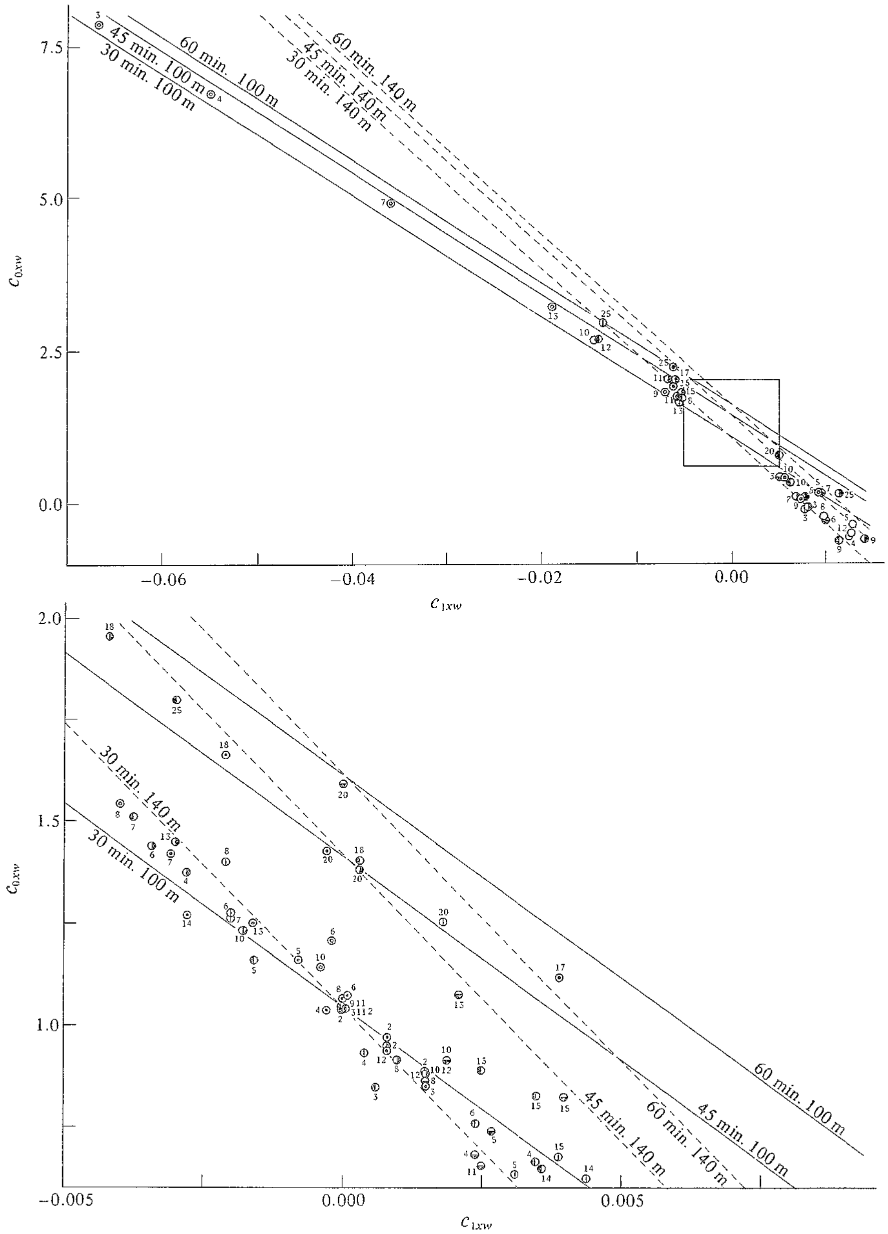

Fig. 8. The distribution of the estimated regression equations of $\log(t_h - 19)$ on the depth fished, in respect of the constant and the coefficient.

Note: The numeral attached to the circle is the catch-class (in tons).

length of the hauling-fastening time according to the depth is mainly in the time for the hauling work. The catch was very good. And it is probable that the influence of the depth on the time for hauling up the net differs according to both the amount of catch and the wave grade, and the influence of the amount of catch differs according to the wave grade. But this fact was not taken into account in the examinations in the preceding sections, although the results in the preceding section suggested that it should be difficult to find any clear result. The results of the preceding two sections showed that few of c_{1xw} were responsible for the significant difference in them. These facts also suggested the necessity of comparing all the estimated relations with one another.

As shown in Fig. 8, the constant and the coefficient varied greatly, but there were rough linear or quadratic relation between them, and the estimated value of t_h through the equations at the same depth within the applicable depth range did not differ greatly. The equations taking smaller c_{1xw} than -0.015 showed the shorter t_h in the deep ground than that estimated from the other equations but the similar t_h in the shallow ground. But most of these equations were applicable to only the shallow ground as shown in Fig. 7. And, practically, large difference was found only in the short t_h in the strata (10.1) and (12.5) in the deep ground. Most of the equations taking larger c_{1xw} than 0.005 showed a short t_h in the shallow ground but they were out of the square or in the triangle enclosed by the lines (20 min. 140 m), (30 min. 100 m), and ($c_{1xw} = -0.005$) in Fig. 8. And, practically, these lines did not show any notable difference in t_h except small t_h in shallow ground in some of the strata taking larger c_{1xw} than 0.005. And the hauls responsible for causing the above-mentioned differences were not many.

All the above-mentioned results were summarized, and it may be said that the influence of the depth on the length of the hauling-fastening time was small and did not vary according to the wave grade and the catch class.

Conclusion

The time for the hauling-fastening work got longer in accordance with the amount of catch, but it was hard to find any clear results on the influence of the following factors on the length of the hauling-fastening time: the depth, the grade of wind wave, and the probable difference in the influence of the amount of catch according to the depth, the wave grade, and the combination of them.

Summary

In the bull trawling for the Alaska pollack in the Bering Sea, the catch was too good to be hauled up on deck, and the cod end containing the catch was separated from the net body and was made fasten alongside the boat after being hauled up. In the preceding report of this series, the change in the time for the towing work was examined. And the change of the time for hauling up the net and for making fasten the cod end observable in the records by the three pairs of the bull trawlers during the entire season for the Alaska pollack in 1964 along the outer edge of the continental shelf of the Eastern Bering Sea was examined in the present report, and the following results were obtained:

1. The frequency distribution of the hauling-fastening time (aggregated into the classes of the nearest 10-min. intervals; abbreviated to t_h) after the stratification of the records according to the grade of wind wave was agreeable to the normal distribution after the log $(t_h - 19)$ transformation, as shown in Fig. 1.
2. The examination on the multiple linear regression of log $(t_h - 19)$ on the amount of catch and the depth revealed that the hauling-fastening time got longer in accordance with the amount of catch in all the wave grades except the roughest extreme and in accordance with the depth in all the wave grades except both the extremes and the grade 5.
3. The similar results were found in the examinations on the linear regression on either of the factors.
4. The examinations on the linear regression on the amount of catch after the twofold stratification of the records according to the wave grade and the depth (into the classes of the nearest 10-m intervals) revealed that 1) the hauling-fastening time significantly got longer in accordance with the amount of catch in the 24 strata, insignificantly longer in the 14 ones, but insignificantly shorter in the five ones out of the 43 ones, 2) not only the constant but also the coefficient of the estimated regression equations varied greatly according to the strata, but the applicable catch ranges of most of the equations showing the different trend from the others were narrow, or the differences were mainly in the extreme catch-classes, and the hauls responsible for notable differences were not many, and 3) it was hard to find any notable differences in the t_h-catch relation according to the wave grade or the depth or the combination of them.
5. The examinations on the regression on the depth after the twofold stratification of the records according to the wave grade and the amount of catch revealed that 1) the length of the hauling-fastening time got significantly longer in accordance with the depth in only the two strata, insignificantly longer in the 54 ones, but insignificantly shorter in the 37 ones, and significantly shorter only in one stratum, 2) the insignificance of the depth regression was not due to the narrow depth range, and 3) the estimated depth-regression equations showed a change in accordance with the amount of catch.
6. It may be concluded that the time for the hauling-fastening work got longer in accordance with the amount of catch, but it was hard to find the influence of the depth and the wave grade not only on the length of this work but also on its elongating trend according to the amount of catch.

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